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BROWN SPOT NEEDLE DISEASE

biology and control in scotch pine plantations

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BROWN SPOT NEEDLE DISEASE--
BIOLOGY AND CONTROL IN SCOTCH PINE PLANTATIONS

Darroll D. Skilling and Thomas H. Nicholls

A P P L I C A T I O N

Christmas tree growers in the north-central States have recently experienced serious losses due to brown spot needle disease, caused by the fungus *Scirrhia acicola* (Dearn.) Siggers. Scotch pine (*Pinus sylvestris* L.) needles infected by this fungus drop prematurely, resulting in unmerchantable trees. Brown spot has been reported in Scotch pine plantations in seven States. Growers with Scotch pine plantations in these States should watch closely for brown spot infection (fig. 1).

The USDA Forest Service after extensive research has recently developed control measures for brown spot needle blight. When properly applied, these controls will eliminate the current losses from this disease.

EARLY DETECTION

Early detection and control of brown spot in Christmas tree plantations will prevent serious economic losses to growers. Generally, 2 to 3 yrs elapse before brown spot reaches epidemic status. During this time the grower can identify the problem and apply control measures. Plantation owners who suspect their trees are infected with brown spot should contact their local extension forester or forest pest management office for assistance. Positive confirmation of brown spot requires isolation and identification of the causal organism. This service is available free of charge from the following agencies:

Plant Disease Clinics, Departments of Plant Pathology, State Universities

Plant Pest Divisions, Departments of Natural Resources or State Departments of Agricuture

Forest Pest Management
State and Private Forestry
USDA Forest Service
6816 Market Street
Upper Darby, PA 19082

Forest Pest Management
State and Private Forestry
USDA Forest Service
1720 Peachtree Rd., NW
Atlanta, GA 30309

SYMPTOMS

The first symptoms of brown spot infection on Scotch pine usually appear in late August. At that time yellow spots develop on the infected needles (fig. 2). These needle spots are often resin-soaked. The majority of the infected needles will be found on the lower branches of the tree, especially on the north side. Infected needles of all ages start dying from the

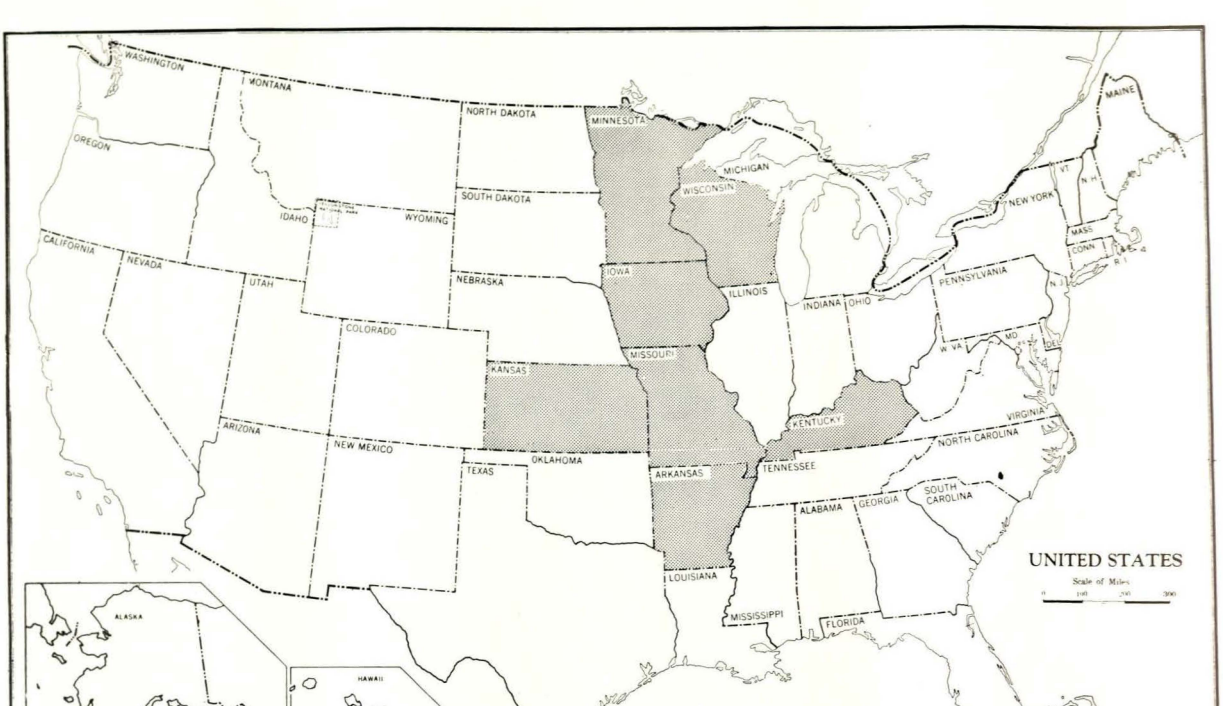

Figure 1.--*Brown spot has been reported in Scotch pine Christmas tree plantations in the seven shaded States. Growers in these States should be alert for brown spot infection in their plantations.*

tips back until entire needles turn brown and fall off during October and November (fig. 3). In lightly infected plantations, only the 2- and 3-yr-old needles are lost. This should not be confused with the normal fall shedding of 3-yr-old needles by Scotch pine. As infection becomes more severe, the current-year needles also are infected and are shed during the fall. The result is mostly bare branches and a totally unsalable Christmas tree. In severe cases branches are killed by the disease, but usually the buds of infected trees remain healthy and produce new foliage the following spring. This new foliage also becomes infected, continuing the disease cycle.

SUSCEPTIBLE HOSTS

Although brown spot is able to infect at least 28 species of pine, it formerly only caused economic losses to longleaf pine in the southern United States (Siggers 1944). With the planting of large areas to Scotch pine for Christmas trees, brown spot now causes serious losses to this species as well. Other Christmas tree species that have been infected by the brown spot fungus in field-inoculation tests include eastern white, Austrian, red, ponderosa, jack, and Virginia pines.

LIFE HISTORY

Two types of spores are produced by the brown spot fungus on longleaf pine in the southern United States. The windblown ascospores provide long-distance spread while the sticky, rainsplash-disseminated conidia are responsible for tree-to-tree spread and for disease buildup on infected trees. In the north-central area, the life cycle on Scotch pine is slightly different. No evidence of windblown ascospores has been found. Evidently, all infection is due to the conidial stage

These conidia are moved about by rain and by other agents such as man or other animals. The conidia infect Scotch pine needles from June to September. The major infection period, however, is in late June and early July. Rainfall is the primary factor for conidia dissemination. Moisture is necessary on the needle surface for germination to occur. New fruiting bodies with mature conidia are found on infected needles in late August (fig. 4). Although many conidia are released from these fruiting bodies in September, little infection seems to take place at this time. The major infection results from overwintering fruiting bodies that release conidia in early summer as the new needles are developing.

CONTROL MEASURES

Chemical

To prevent infection of new foliage, a fungicide must be applied in plantations where brown spot occurs. No natural controls are known for susceptible Scotch pine varieties. The disease may subside during dry years but will increase again when moisture conditions return to normal. Prompt control measures will maintain tree vigor and minimize losses from other insect and disease problems.

When to Spray

Applying fungicides at the proper time is essential for satisfactory brown spot control. The fungicides must be applied before needle infection by the fungus spores. Once infection takes place treatment is not effective. The first spray should be applied when the new needles are about half grown. In the north-central region this is about mid-June. In severely infected plantations or during unusually wet years, a second spray should be applied 3 to 4 weeks later.

What to Use

Two fungicides are currently recommended for use against brown spot in Scotch pine plantations--Bordeaux mixture and chlorothalonil. Both are registered for this purpose.

Christmas tree growers in Wisconsin have been spraying with Bordeaux mixture for 3 yrs and have found it to be safe and effective. It also remains active on the needle surface longer than many other fungicides. Bordeaux mixture, however, has some disadvantages. The material is difficult and time-consuming to prepare due to its poor water solubility. It is also alkaline and is not compatible with many insecticides. Because of these problems, many growers prefer to use other fungicides.

Chlorothalonil (sold under such trade names[1] as Bravo and Daconil) is also effective for control of brown spot. This fungicide has only recently been registered for this purpose. Although more expensive than Bordeaux mixture, it is easily prepared and is not corrosive to equipment. It is also very effective against *Lophodermium* needlecast, another serious disease of Scotch pine plantations. Because of its advantages over Bordeaux mixture, the use of chlorothalonil for brown spot control probably will increase.

How to mix.--Chlorothalonil is relatively easy to prepare. The wettable powder is added to the water in the spray tank and agitated. No spreader-sticker is necessary. The recommended rate is 2.5 lb/100 gal of water for hydraulic sprayers and 6 lb/100 gal of water for mist blowers.

To use Bordeaux mixture, a few additional steps are necessary. Bordeaux is a mixture of copper sulfate (instant powder, blue vitriol) and hydrated lime in water. For control of brown spot with hydraulic sprayers, a mixture of 8 lb copper sulfate, 8 lb hydrated lime, and 100 gal of water is recommended. Growers normally use a 24-24-100 mixture when using mist blowers. In preparing the mixture, the solutions of copper sulfate and lime should be made separately. Using 8-8-100 formula, 8 lb of copper sulfate are dissolved in 50 gal of water and 8 lb of hydrated lime are dissolved in another 50 gal of water. When the mixture is to be used, pour the two solutions together through a copper sieve (about 20 meshes to the inch) to exclude small particles that may plug spray nozzles. Constant agitation is necessary to prevent the material from settling to the tank bottom. Because Bordeaux mixture loses some of its effectiveness within a few hours after preparation, material remaining in the sprayer at the end of the day should be discarded according to approved pesticide disposal methods. Bordeaux mixture is very corrosive to most metal equipment. Fiberglass

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[1] *Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

Figure 2.--*Needle spots caused by the brown spot fungus,* Scirrhia acicola. *In the North Central States these spots appear in late August.*

Figure 4.--*The brown spot fruiting bodies are visible on infected needles by late August. Major infection takes place the following late June or July by means of rainsplash-disseminated conidia.*

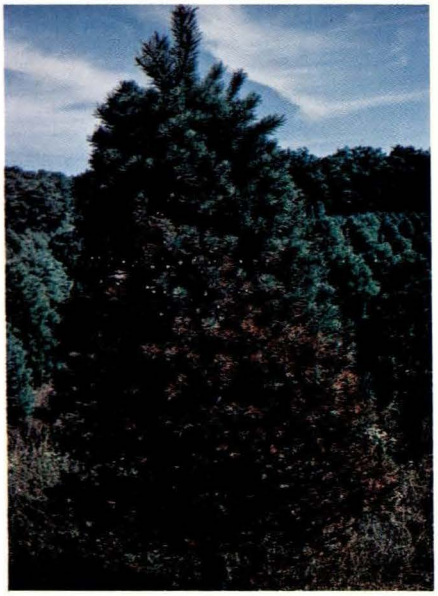

Figure 3.--*Brown spot infection is more severe on the lower portion of the tree, especially on the north side where moisture conditions are most conducive to infection.*

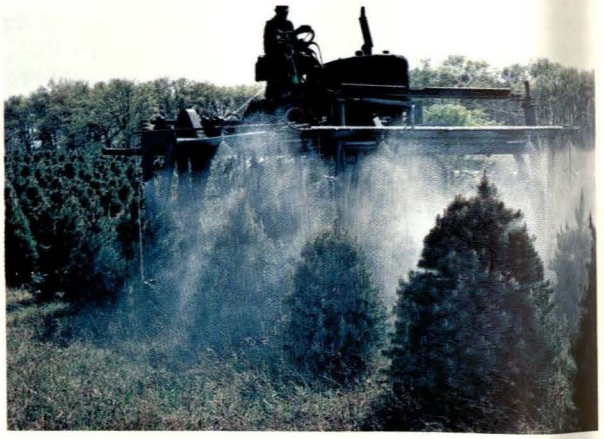

Figure 5.--*Hydraulic sprayers such as this straddle type are very effective for applying fungicides to control foliage diseases in Christmas tree plantations.*

Figure 6.--*Mist blowers in general are more economical for Christmas tree spray operations than the hydraulic type. The large blowers develop windspeeds of 95 mi/h and can spray up to 20 rows of trees if the road system permits spraying from both sides.*

or stainless steel tanks are recommended and all spray equpiment must be washed and rinsed thoroughly at the end of the day.

Application equipment.--Most growers apply fungicides with hydraulic sprayers or mist blowers. To be effective, the hydraulic sprayer must have a working pressure sufficient to completely moisten all tree foliage (fig. 5). Hydraulic sprayers use about 100 gal of fungicide/acre. In general, hydraulic sprayers cover less area per hour than airblast mist blowers. The latter can spray up to 20 rows of trees if the road system permits spraying the trees from both sides (fig. 6). A large mist blower will develop windspeeds of 95 mi/h and cover about 8 acres of plantation/hr. Most mist blowers use about 40 gal of fungicide/acre, which is considerably less than the hydraulic sprayers use and explains the use of a more concentrated mixture. The new low-volume mist blowers use only about 20 gal/acre. Here the concentration of Bordeaux mixture is 12-12-20.

Weather

To be effective, fungicides should be allowed to dry on the needles; therefore, they should not be applied during rain. Subsequent rainfall is not as detrimental. Foliage should be sprayed when the air is calm to obtain even coverage.

Safety Precautions

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels. Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed.[2/]

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of presticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

Cultural Control

In addition to chemical control, the following cultural practices will either prevent brown spot infection or reduce its severity.

Plant only healthy nursery stock. It is far easier to keep disease out of a plantation than to control it once it is established. Although State nursery inspection is improving, there have been many cases in recent years in which diseased stock was shipped from nurseries. If stock has turned brown or contains infection spots on the foliage, the trees should be examined by a plant pathologist before planting. If brown spot or other foliage diseases are present, the trees should be returned to the nursery.

Plant resistant varieties. The short-needled Scotch pine are more susceptible to the brown spot fungus than the long-needled varieties. The varieties "Spanish" and "French-green" are especially susceptible. To avoid catastrophic losses, a grower should avoid planting all his land in one species or one variety.

[2]*Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.*

Avoid planting Scotch pine seedlings next to older Scotch pine windbreaks. Trees in windbreaks frequently serve as a reservoir for the brown spot fungus as well as for other diseases and insects. If planting near windbreaks is unavoidable, the windbreak trees should be cut and burned the year before planting the new stand. Stumps should be removed or treated with a registered insecticide for weevil control.

Cut and remove small pockets (1 to 5 trees) of brown-spot-infected trees in a plantation. All remaining trees within 30 ft of the infected area should be sprayed with a fungicide at the proper time. A backpack mist blower works well for this type of operation. If there are several pockets of infected trees, the whole plantation should be sprayed as outlined earlier.

Avoid leaving live branches on stumps when harvesting trees, especially in infected plantations. These lower branches are especially susceptible to foliage diseases such as brown spot. Needles on these lower branches serve to perpetuate the brown spot fungus.

Remove infected trees as soon as they have been cut. Brown spot spores are produced throughout the growing season. Unless infected trees cut during the spring are removed, they will produce spores into the fall.

Do not shear infected plantations during wet weather. Brown spot spores ooze out of fruiting bodies when the foliage is wet and can easily be spread from tree to tree on shearing tools or workers' clothing. Healthy plantations should be sheared first to avoid carrying spores into them from diseased plantations. If this is not practical, the shearing tools should be sterilized with denatured alcohol for 3 to 5 min after shearing infected plantations.

DOCUMENTATION

Brown spot disease has recently caused damage in seven north-central States. These States grow 31 percent of the Nation's Christmas trees at a market value of more than $70 million. Wisconsin was hardest hit of these States; from 1967 through 1970, several hundred thousand Scotch pines were unsalable because of brown spot infection (Skilling and Nicholls 1972, Prey and Morse 1971).

After discovery of brown spot needle disease in Wisconsin, research studies were begun to develop practical control measures for this serious disease. The research involved (1) studying the life history of the causal organism, *S. acicola*, (2) host range studies, and (3) fungicide evaluation for disease control.

LIFE HISTORY STUDY

The primary objective of this study was to determine what influence the temperate Lake States environment had upon the biology and life history of the brown spot fungus and at what points in its life cycle it was most vulnerable to control. Specifically, we investigated (1) how climate affected the biology of the fungus, (2) how the fungus overwinters, (3) the seasonal development of host and parasite, (4) how spores are disseminated, and (5) when infection takes place.

Methods

Climate and Phenology

Disease development is affected by climatic conditions. To obtain a measure of the various conditions, weather stations were maintained in several areas in Wisconsin and Minnesota during 1970 and 1971. Each station consisted of a weather shelter containing a temperature-relative humidity, 7-day recording hygrothermograph, and a rain gage (fig. 7) which were serviced at weekly intervals. The resulting weather data were correlated with the seasonal development of the disease and the host.

At each weather station phenological records of parasite and host development were made at weekly intervals throughout the growing season (April to October) and at lesser intervals during the other months. These data provided a graphic summary of new needle growth, timing of spore discharge and dissemination, infection periods, and symptom development.

Spore Release and Dissemination

1970.--To trap brown spot spores, six vaseline-coated microscope slides were placed in brown-spot-infected Scotch pine Christmas tree plantations near Black River Falls, Wild Rose, and Boscobel, Wisconsin, and near Hastings, Minnesota (fig 8). Two of the slides were placed directly under infected Scotch pine trees, two were placed in the upper crowns, and two were placed in the open short distances from infected trees. These slides were changed at weekly intervals to provide information on short-distance dissemination of spores. To determine the long-distance dissemination of spores slides were placed from 5 to 3,520 yd in various directions from infected trees. Slides were also placed in an infected 35-yr-old Scotch pine windbreak that was adjacent to a Scotch pine Christmas tree plantation near Brodhead, Wisconsin. These slides were changed at irregular intervals throughout 1970.

The duration of spore discharge from cut brown-spot-infected Scotch pine Christmas trees was determined at Black River Falls by placing the trees on top of a wire frame located 4 ft above the ground. The infected trees were left on the frame from May until the end of September 1970 to see how long cut trees produce brown spot conidia. To measure this factor, two vaseline slides were placed under the infected trees. The slides were periodically changed and the spores counted. Before the frame was put in place, susceptible pine seedlings were planted to serve as indicators of infection.

1971.--Similar procedures were followed in 1971. Some of the slide locations were changed to obtain more detailed information on short-distance spread of spores between closely planted Christmas trees. Six slides were also used to determine the effect of fungicides on spore production.

The study areas were the same as in 1970 except the Hastings, Minnesota, study area

was replaced by one near Trempealeau, Wisconsin. As in 1970, six slides were used at each plantation. Two were placed under infected trees, but the other four were placed at the cardinal directions 1 to 54 in. from infected trees. Of the six slides used in the heavily infected Trempealeau plantation, two were placed under unsprayed trees, two under trees sprayed with Du-ter (triphenyltin hydroxide), and two under trees sprayed with Fundilan (a mixture of chlorothalonil and cycloheximide). Some slides were left out from November through April to see if any spores were released during the winter months.

Field observations indicated that as Scotch pine needles grow older they are more resistant to brown spot infection. To verify this observation, potted greenhouse-grown Spanish Scotch pine seedlings were exposed to brown spot spores by placing them under heavily infected Scotch pine Christmas trees for various time intervals throughout the growing season. The potted seedlings were then removed to a greenhouse and observed for symptom development on the current-year needles.

Results

Climate and Phenology

The disease symptoms and life history of the fungus described earlier in this paper were based on the phenological development of the brown spot disease on Scotch pine (table 1).

Brown spot pycnidia were present throughout the year although more abundant at certain times than others. Rainfall and low temperatures were the most critical weather factors influencing spore release. Spores were released throughout the growing season but only during rainy weather. Spore release decreased rapidly or stopped as temperatures approached 2° C (35° F).

Spore Release and Dissemination

Spore release throughout the growing season was correlated with rainfall and current-year needle growth (figs. 9 and 10). Generally, two spore peaks occurred, one in June and one in late August and September as seen below:

Spore trapping period[3]	*Conidia trapped (Number)*
June 3 - June 5, 1970	17
June 5 - June 29, 1970	2,232
June 29 - July 21, 1970	446
July 21 - Aug. 21, 1970	161
Aug. 21 - Sept. 30, 1970	858
Sept. 30 - Oct. 30, 1970	282
Oct. 30 - Dec. 1, 1970	22
Dec. 1, 1970 - May 5, 1971	0

[3] *Number of brown spot conidia collected in an infected 35-yr-old Scotch pine windbreak near Brodhead, Wis., based on two spore traps for each period.*

Table 1.--*Average dates of needle growth and brown spot fungus development on current-year Scotch pine needles in Wisconsin and Minnesota, 1970 and 1971*

Location[1]	Start of new needle	Current-year needle growth complete	Appearance of needle spots on current-year needles	Appearance of browning and fruiting bodies on current-year needles	Dropping of current-year needles began
Brodhead, Wis.	5/17	7/15	8/13	8/24	9/17
Boscobel, Wis.	5/17	6/28	8/2	8/13	8/31
Trempealeau, Wis.	5/10	7/12	8/16	8/9	8/23
Wild Rose, Wis.	5/31	7/23	8/17	9/7	9/24
Black River Falls, Wis.	5/21	8/10	8/9	8/16	9/17
Hastings, Minn.	6/7	8/20	8/18	8/31	9/29

[1] Locations listed from the southern to northern parts of the State.

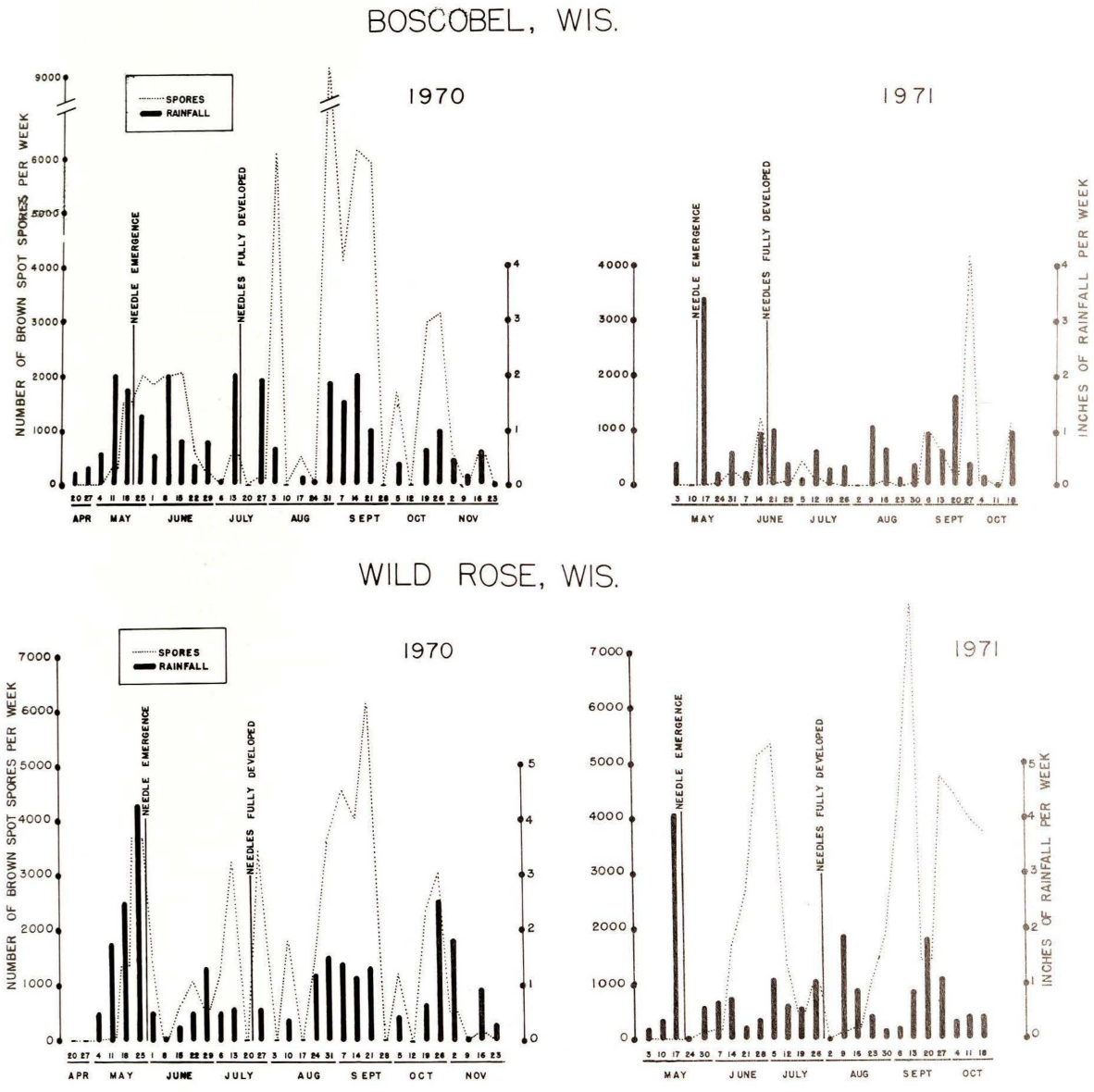

Figure 9.--*Weekly rainfall, and numbers of brown spot conidia trapped weekly in infected Scotch pine plantations at Boscobel and Wild Rose, Wisconsin. Spore number equals the total number of spores counted on three sample strips taken on each of six spore trap slides in each plantation.*

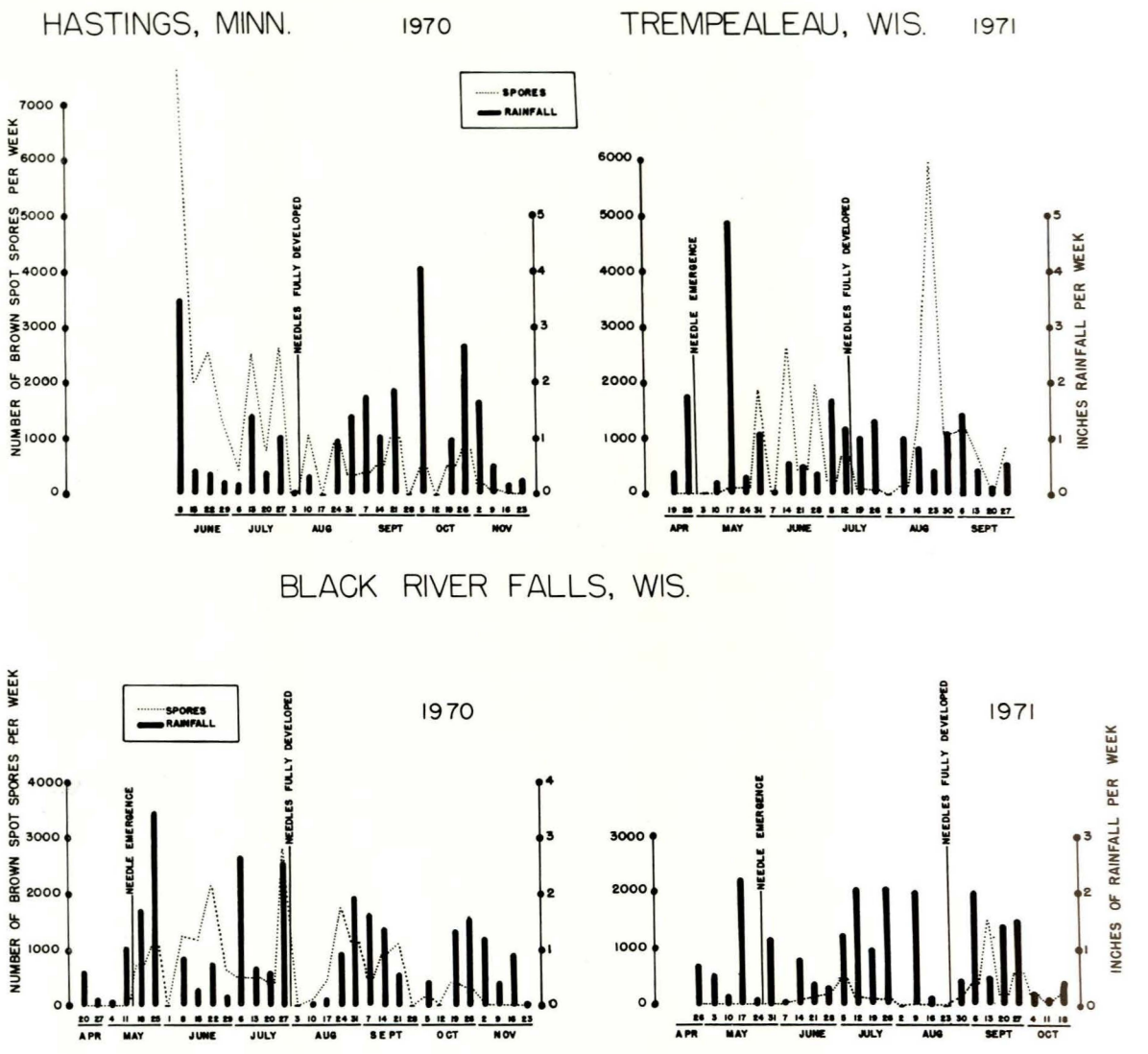

Figure 10.--*Weekly rainfall, and numbers of brown spot conidia trapped weekly in infected Scotch pine plantations at Hastings, Minnesota, and Black River Falls and Trempealeau, Wisconsin. Spore numbers equals the total number of spores counted on three sample strips taken on each of six spore trap slides in each plantation.*

Spores released during the first peak are the most important in terms of infecting the new needles. A fungicide must be applied before this peak to prevent infection. Young, growing Scotch pine needles are more susceptible to infection than mature needles. Despite the abundant spore release during late August and September, little infection occurs because the needles are more resistant. Heavy infection occurred on trees exposed between June 26 and July 24, little infection occurred on trees exposed after July 24, and no infection occurred on trees exposed after September 6 (table 2).

Table 2.--*Needle infection of Spanish Scotch pine seedlings placed under infected Scotch pine Christmas trees at Hastings, Minn. and Wild Rose, Wis.*[1]

Period subjected to spore casts 1972	Disease rating[2]	Amount of rainfall
		Inches
HASTINGS, MINNESOTA		
5/15 to 5/30	0	1.33
6/9 to 6/26	0.8	2.00
6/26 to 7/10	2.7	1.38
7/10 to 7/24	2.3	4.29
7/24 to 8/7	.3	1.68
8/7 to 8/18	.3	.30
8/18 to 9/6	.2	2.89
9/6 to 9/18	0	.78
9/18 to 10/16	0	3.72
WILD ROSE, WISCONSIN		
6/6 to 9/6	4.0	9.53
9/6 to 10/4	0	2.00

[1]Three to seven seedlings were placed under the infected tree, left for the indicated period of time, and returned to a greenhouse for symptom development. Symptom readings were made on December 14, 1972.

[2]Based on a scale of 0 to 4: 0=no infection, 1=1 to 25 percent of needles infected, 2=26 to 50 percent of needles infected, 3=51 to 75 percent of needles infected, and 4=76 to 100 percent of needles infected.

Spore release was dependent on the occurrence of rainfall (figs. 9 and 10). Despite adequate rainfall, few spores were released in April and November, probably due to low temperatures. No spores were trapped from December through the end of April.

Brown spot spores were collected on 750 slides exposed at 24 locations within and some distance from brown-spot-infected Scotch pine trees in 1970. Most spores were trapped in the lower crowns of trees while only a few spores were trapped 1 to 10 ft from infected trees (table 3). This resulted from rainsplash dissemination of spores and the greater number of fruiting bodies present in the lower crowns.

As in 1970, the 1971 data show that the majority of spores were trapped within or under infected trees (table 4). Significantly fewer spores were trapped from 1 to 54 in. away from infected trees. However, the 1970 and 1971 data show that enough rainsplash spores are disseminated short distances to spread the fungus between closely planted Christmas trees.

Means for long-distance dissemination of the fungus has not been determined in the North. Despite the exposure of more than 1,300 spore trap slides during 1970 and 1971, no brown spot ascospores were collected. Numerous infected needles were also examined at different times of the year, but no perfect-stage fruiting bodies were found. This is in contrast to the southern United States where both conidia and ascospores are common on longleaf pine (Kais 1971). The most northern record of the perfect stage was made near Ashland, Missouri, on ponderosa pine (*Pinus ponderosa* L.) (Luttrell 1949).

Evidence was found for two other possible means of long-distance spore dissemination: insect and man. Insect dissemination of brown spot conidia may be possible because the spores are sticky and numerous insects inhabit the plantations. During June 1970, two scales of a lepidopterous insect were observed on a spore trap 10 ft from the nearest infected tree. Twenty-five brown spot conidia were attached to these scales. If spores such as this were to come in contact with susceptible tissue, infection might result. Spores also may be spread by shearing. If infected trees are sheared while the foliage is wet, the sticky spores can be carried on shearing tools. This was determined by applying the sticky side of cellophane tape to the blades of shearing knives that had been used to shear wet brown-spot-infected trees and then placing this tape on glass slides. Microscopic examination revealed hundreds of brown spot conidia on the tapes. This suggests conidia are spread from one tree to another or within the same tree during shearing, which could be a significant means of spore dissemination within Christmas tree plantations.

Table 3.--*Total number of brown spot conidia collected by spore traps placed at random locations within and near infected Scotch pine trees*

Study area	Spore trapping period (1970)	Total slides exposed	Location of spore traps	Conidia trapped[1]	Total rainfall during trapping period
		Number		*Number*	*Inches*
Black River Falls, Wis.	Apr. 20 to Nov. 30	66	Upper crown	7,786	28.13
		66	Under tree	10,904	
		33	1 ft from tree	65	
		33	5 ft from tree	14	
Boscobel, Wis.	Apr. 20 to Nov. 30	66	Upper crown	23,457	25.11
		66	Under tree	28,403	
		33	1 ft from tree	470	
		33	5 ft from tree	58	
Wild Rose, Wis.	Apr. 20 to Nov. 30	66	Upper crown	15,895	26.20
		66	Under tree	30,114	
		33	1 ft from tree	245	
		33	5 ft from tree	15	
Hastings, Minn.	June 8 to Nov. 30	52	Upper crown	2,845	24.58
		52	Under tree	22,888	
		26	2 ft from tree	19	
		26	10 ft from tree	3	

[1]All brown spot conidia were counted on three random vertical strips across the width of each slide using a microscope at 430X.

Table 4.--*Total number of brown spot conidia trapped on 25 slides[1] placed under and at various distances from infected Scotch pine trees*

Study area	Distance and location from crown edge of infected trees	Conidia trapped[2]	Total rainfall
	Inches	*Number*	*Inches*
Black River Falls, Wis.	10 north	42	21.37
	11 east	10	
	8 south	8	
	6 west	73	
	0 under tree	1,891	
	0 under tree	2,371	
Wild Rose, Wis.	8 north	1,803	17.82
	7 east	3,233	
	5 south	3,446	
	1 west	3,552	
	0 under tree	18,342	
	0 under tree	21,279	
Boscobel, Wis.	54 north	5	15.54
	27 east	18	
	54 south	13	
	42 west	31	
	0 under tree	3,063	
	0 under tree	6,583	

[1]A different slide was exposed during each of 25, 7-day time intervals between May 3 and October 25, 1971, at each location.

[2]All brown spot conidia were counted on three random vertical strips across the width of each slide using a microscope at 430X.

Brown-spot-infected Scotch pine Christmas trees cut in May 1970 released spores from May 20 to September 28 as seen below:

Spore trapping period[4]	*Conidia trapped (Number)*
May 20 - May 30	1,927
May 30 - June 7	1,152
June 7 - June 18	5,084
June 18 - July 16	7,617
July 16 - July 23	573
July 23 - Aug. 7	2,313
Aug. 7 - Aug. 22	392
Aug. 22 - Sept. 10	729
Sept. 10 - Sept. 28	254
Sept. 28 - Oct. 28	0
Oct. 28 - Nov. 30	0

Susceptible seedlings grown under these cut trees became infected. Therefore, infected trees that are cut should be removed from the plantation or destroyed. An evaluation of inoculum remaining in a plantation after merchantable and unmerchantable materials had been cut revealed that branches with infected needles remained on 86 percent of the stumps (N=50). Many of these branches were in contact with adjacent uncut trees and presumably could cause infection of these trees. Therefore, all infected trees should be cut below the bottom whorl of branches to reduce this potentially important source of inoculum.

The incidence of trapped brown spot spores under infected Scotch pine was dramatically reduced by fungicide treatment (table 5). Du-ter and Fundilan fungicide sprays protected new foliage while the new foliage of unsprayed trees became infected. The newly infected foliage produced fruiting bodies and released thousands of spores in the latter half of the growing season. The fungicide-treated trees produced very few spores by comparison.

The decrease in spores from 1970 to 1971 for the Boscobel area was not due to fungicide control (fig. 9). Instead, it was due to extremely heavy infection in previous years. As a result, by 1971 many trees were almost devoid of foliage and some trees actually lost all their needles and died. Because of this lack of infected foliage, there were fewer fruiting bodies present so the number of spores released in 1971 decreased sharply.

[4] *Number of conidia collected under recently cut brown-spot-infected Scotch pine Christmas trees. Two vaseline-covered slides were exposed during each period.*

Table 5.--*Effect of fungicide treatment on spore discharge*

Spore trapping period	Treatment	Conidia trapped[1]
		Number
Apr. 19 - June 28	Unsprayed	2,411
	Du-ter[2]	1,146
	Fundilan[3]	1,721
June 28 - Aug. 16	Unsprayed	2,247
	Du-ter	421
	Fundilan	82
Aug. 16 - Oct. 4	Unsprayed	9,381
	Du-ter	478
	Fundilan	75

[1] Reduction in spore discharge due to prevention of new infection and mechanical reduction of inoculum by air blast at time of spraying.

[2] Trees sprayed on June 23, 1971, with Du-ter (12 oz commercial/100 gal water).

[3] Trees sprayed on June 23, 1971, with Fundilan (96 oz commercial/100 gal water).

HOST RANGE STUDIES

Methods

The potential impact of the brown spot disease on conifer species in the Lake States was determined by field inoculation experiments. Red pine (*Pinus resinosa* Ait.), eastern white pine (*P. strobus* L.), jack pine (*P. banksiana* Lamb.), Austrian pine (*P. nigra* Arnold), white spruce (*Picea glauca* (Moench) Voss), and four varieties of Scotch pine were exposed to natural infection by planting under heavily infected Scotch pine Christmas trees or windbreaks in five different areas in Wisconsin and Minnesota between 1970 and 1972. Longleaf pine (*Pinus palustris* Mill.) was also tested for susceptibility because it is the classical host for the brown spot fungus in the southern United States.

These trees were examined for symptoms of brown spot infection each fall. The amount of infection present in current-year and 1-yr-old needles was recorded according to the following classification system:

0=no infection;
T=less than 1 percent of needles infected;
1=1 to 25 percent of needles infected;
2=26 to 50 percent of needles infected;
3=51 to 75 percent of needles infected; and
4=76 to 100 percent of needles infected.

Isolations were made periodically from infected needles to confirm the presence of the brown spot fungus.

Results

Spanish and French-green Scotch pine varieties were highly susceptible to brown spot, as was Austrian pine (table 6, fig. 11). The long-needled Austrian Hills and German varieties of Scotch pine varied between moderately susceptible to moderately resistant, with the German variety being the most resistant to brown spot.

Red pine, which was moderately susceptible, is recognized as a new host to brown spot infection (Nicholls and Hudler 1972) (fig. 11). Older red pine needles were more susceptible to infection than were current-year needles (table 6). In addition, red pine appears to gain resistance as it grows older. However, brown spot could cause serious damage to red pine seedlings grown in nurseries or to seedlings out-planted among or adjacent to brown-spot-infected Scotch pine Christmas tree plantations or windbreaks.

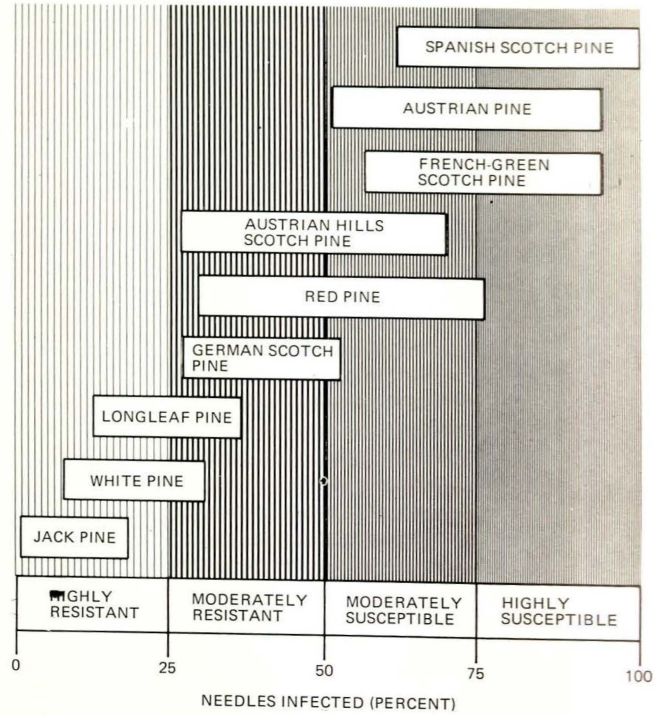

Figure 11.--*Range of conifer susceptibility or resistance to the brown spot fungus.*

Table 6.--*Average degree of brown spot infection of conifer seedlings planted under brown-spot-infected Scotch pine trees located near Black River Falls, Wild Rose, and Brodhead, Wis., and Hastings, Minn.*

Species	Month and year of evaluation											
	September 1970				September 1971				October 1972			
	1969 needles		1970 needles		1970 needles		1971 needles		1971 needles		1972 needles	
	Degree of inf.[1]	Trees	Degree of inf.	Trees	Degree of inf.	Trees	Degree of inf.	Trees	Degree of inf.	Trees	Degree of inf.	Trees
		Number		*Number*		*Number*		*Number*		*Number*		*Number*
Spanish Scotch pine	3	119	2	158	4	73	3	150	4	9	4	58
French-green Scotch pine	2	96	2	149	4	40	3	138	3	22	3	113
Austrian Hills Scotch pine	2	109	1	154	3	95	2	151	1	27	1	140
German Scotch pine	1	104	1	143	2	123	1	142	1	40	1	118
Austrian pine	--	--	--	--	--	--	--	--	4	117	2	110
Red pine	1	145	0	142	3	123	T	133	3	621	T	619
White pine	T	108	0	131	1	85	T	127	1	73	1	118
Jack pine	T	131	0	130	1	125	T	129	T	98	0	103
Longleaf pine	--	--	--	--	--	--	1	82	--	--	1	81
White spruce	--	--	--	--	--	--	--	--	T	89	0	91

[1]Infection code: 0=no infection; T=less than 1 percent of needles infected; 1=1 to 25 percent of needles infected; 2=26 to 50 percent of needles infected; 3=51 to 75 percent of needles infected; 4=76 to 100 percent of needles infected.

Of the three native Lake States pine species, red pine was the most susceptible to brown spot, white pine was moderately to highly resistant, and jack pine was highly resistant (fig. 11). Only a trace of infection was found on white spruce.

High seedling mortality (20 to 83 percent) occurred in the short-needled Spanish and French-green Scotch pine varieties after 3 successive years of heavy defoliation caused by brown spot. There was very little mortality (3 to 5 percent) in the long-needled German and Austrian Hills Scotch pine varieties. These results agree very well with the average degree of foliage infection for these varieties (table 6). This again illustrates the high resistance of long-needled Scotch pine varieties to brown spot.

Although longleaf pine became infected during the study, it was still quite resistant. Evidence indicates that there are races of *S. acicola* and that the northern race is not as pathogenic on longleaf pine as the southern race (Kais 1972). This may explain the resistance shown by longleaf pine in this study.

FUNGICIDE STUDIES

Laboratory Tests

Fifteen fungicides were screened in the laboratory for activity against the brown spot fungus using the modified paper disk bioassay method (Sharvelle and Pelletier 1956). Different amounts of fungicides dissolved in acetone were applied to small filter paper disks (12.7 mm). Each disk was inoculated with 0.024 ml of a suspension of brown spot conidia. The inoculated disks were placed in petri dishes with potato dextrose agar at 20° C for 5 days. The relative density of mycelial growth was then recorded. If no mycelium was observed after 10 days, the disk was removed to a different spot on the agar and turned over to determine whether the test material was fungicidal or fungistatic to *S. acicola*. The fungicides tested were:

1. Manganous ethylenebis [dithiocarbamate] (maneb) (Manzate 70W).
2. Bordeaux mixture (8-8-100).
3. *N*-[(trichloromethyl)thio]phthalimide (folpet) (Phaltan 50W).
4. Cis-N-(1,1,2,2-Tetrachloroethylthio) -4-cyclohexene-1,2-dicarboximide (captafol) (Difolatan 4F).
5. Zinc dimethyl-dithiocarbamate (ziram) (Zerlate 76W).
6. Methyl 1-(butyl carbamoyl)-2-benzimidazole carbamate (benomyl) (Benlate 50W).
7. Bis(dimethylthiocarbamoyl) disulfide (thiram) (Thylate 99W).
8. Tetrachloroisophthalonitrile (chlorothalonil) (Bravo W75).
9. A mixture of chlorothalonil plus 0.025 percent cycloheximide (Fundilan 75W).
10. Cuprous oxide.
11. 2-(thiocyanomethylthio) benzothiazole (TCMTB 30W).
12. 2-(4-thiazolyl) benzimidazole (Tobaz 25W).
13. Triphenyltin hydroxide (Du-ter 47.5W).
14. Alpha-(2,4-dichlorophenyl)-alpha-phenyl-5-pyrimidine methanol (Triarimol, EL-273).
15. 1,2-Bis(3-methoxy carbonyl-2-thioureido) benzene (Topsin 70W).
16. 3-(3,5-dichlorophenyl)-5,5-dimethyl oxazolidine-dione-2,4 (dichlozoline) (Sclex 30W).
17. Piperazine-1,4-diyl-bis-1-(2,2,2-trichloroethyl) formamide (Cela W524).

Bordeaux mixture, Du-ter, Ziram, and Benomyl were strongly fungicidal to the brown spot organism and were selected for preliminary field evaluation. Chlorothalonil and Fundilan were tested later and found to be fungicidal to *S. acicola* and were added to the field test.

Field Tests and Results

Wautoma Area

The study area near Wautoma, Wisconsin, was a 10-yr-old Christmas tree plantation that contained 6-ft-tall French-green Scotch pine heavily infected with the brown spot fungus. All fungicides were applied with a backpack mist blower at the rate of 1 pt/tree (fig. 12).

1970.--Fungicides tested were Bordeaux mixture (8-8-100), Du-ter (12 oz commercial/100 gal water), benomyl (12 oz/100 gal water), and ziram (96 oz/100 gal water). DuPont surfactant F was added to the benomyl, and DuPont spreader-sticker was added to the ziram.

Four different spray schedules were tested with each fungicide: (1) trees sprayed on May 20 only; (2) trees sprayed on June 25 only; (3) trees sprayed on May 20 and June 25; and (4) trees sprayed on May 20, June 25, and August 18.

Each treatment was applied to a row of 10 trees in each of 3 replications in a modified randomized block design. Each row of sprayed trees was separated from other treated rows by a buffer row of unsprayed trees. Ten unsprayed trees were included in each replication as a control.

Treatments were evaluated on September 21, 1970, and again on May 26, 1971. Each tree was examined for brown spot symptoms and was assigned a disease rating. Only 1970 needles were rated. The rating system was:

0=no infected needles present;
1=1 or 2 branches with infected needles;
2=several branches with infected needles; and
3=tree heavily infected (over 25 percent of branches with infected needles).

Trees rated 0 or 1 were classified as merchantable Christmas trees.

Evaluations made in fall 1970 and spring 1971 showed that all fungicides tested gave excellent control of brown spot on trees sprayed in June, May-June, or May-June-August (figs. 13 and 14). The May-only treatment was not effective because the new needles had not emerged from the needle sheath at time of spraying. There was no evidence of disease eradication by any of the test fungicides when applied in May only. The June-only spray was the most economical. No evidence of additional disease control resulted from the August spray. Although spore-dissemination studies showed spores being cast during late summer, there was no evidence of increased brown spot symptoms between the fall and spring evaluations.

1971.--The same fungicides and concentrations were used but the spray schedules were adjusted on the basis of the 1970 test results. The spray schedules were: (1) trees sprayed on June 25 only; (2) trees sprayed on August 12 only; and (3) trees sprayed on June 25 and August 12. The trees were evaluated for brown spot symptoms on October 6, 1971, using the same rating system used in 1970.

The 1971 results were similar to those from 1970. All fungicides were effective using the June 25 spray. The August-only spray was not effective because infection took place before fungicide use. There was a rapid buildup of brown spot infections on the August-sprayed trees. The inoculum for this probably came in part from the unsprayed, heavily infected trees on each side of the test row.

Trempealeau Area

In 1971 a new brown spot fungicide test was installed in a heavily infected 11-yr-old Scotch pine plantation near Trempealeau, Wisconsin. The stand was a mixture of short-needled varieties, with Spanish and French-green predominating. All fungicides were again applied with a backpack mist blower at the rate of 1 pt fungicide/tree.

Four fungicides were used in the Trempealeau test: Bordeaux mixture (8-8-100), Du-ter (12 oz commercial/100 gal water), Fundilan (96 oz/100 gal water), and ziram (96 oz/100 gal water). DuPont spreader-sticker was again added to the ziram.

Spray schedules were: (1) trees sprayed June 23 only; and (2) trees sprayed June 23 and August 10.

Each treatment was applied to a 10-tree row in each of 3 replications. Treated rows were separated by a buffer row of unsprayed trees. Thirty trees were included in each replication as a control. Treatments were evaluated on October 5, 1971, with the same rating system used at Wautoma.

Fundilan was the only fungicide that gave satisfactory control under the extreme infection hazard present in this plantation (table 7). Again, the June-only spray was about equal in effectiveness to the June and August spray.

Pilot Test

In 1972 a pilot test of fungicides was installed in Christmas tree plantations near Black River Falls and Poy Sippi, Wisconsin, using large air-blast mist blowers. Both plantations were Scotch pine, variety unknown, 4 to 8 ft tall.

The Black River Falls plantation was sprayed on June 14, 1972, with Bordeaux mixture (8-8-100) and Bravo W75 at 96 oz/100 gal water. The Bordeaux mixture-treated area was 1.5 acres, the Bravo area was 0.4 acre, and the unsprayed area was 0.9 acre. On October 10, 1972, 100 trees in each area were selected at random and evaluated using the same rating system as in prior studies. The

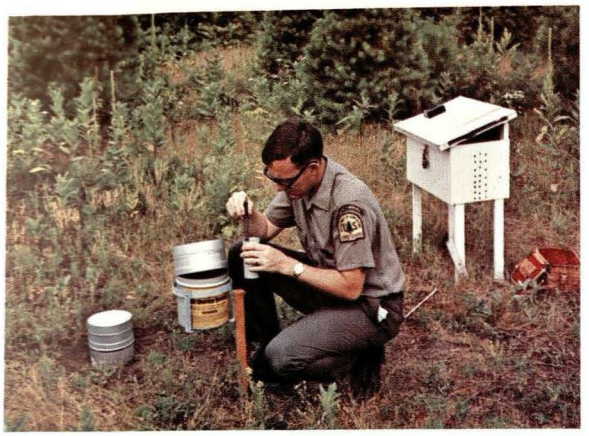

Figure 7.--*Weather stations, located in Christmas tree plantations, were used to correlate weather with infection periods and with seasonal development of the brown spot fungus.*

Figure 8.--*Vaseline-coated microscope slide used to collect conidia of the brown spot fungus.*

Figure 12.--*Test fungicides were applied with a backpack mist blower at the rate of 1 pt/tree.*

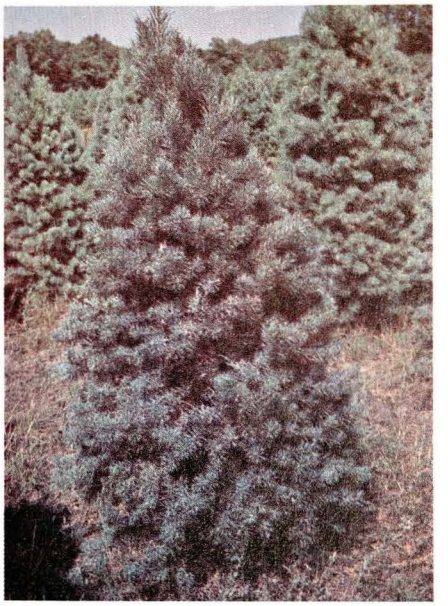

Figure 13.--*Scotch pine sprayed with Bordeaux mixture for control of brown spot. Compare with the neighboring untreated tree in figure 14.*

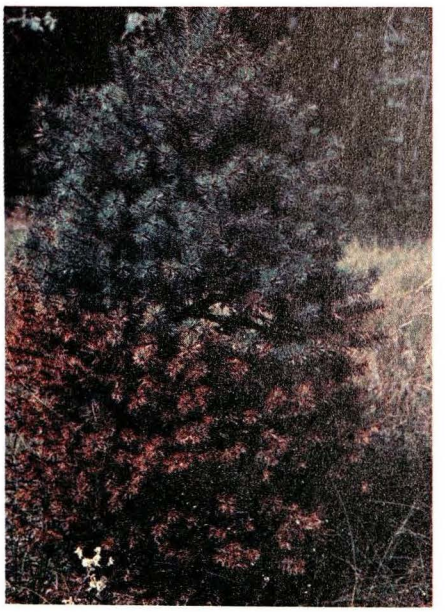

Figure 14.--*Unsprayed Scotch pine with severe symptoms of brown spot needle blight.*

Table 7.--*Brown spot fungicide test, Trempealeau, Wis., 1971*

Fungicide formulation	Rate/ 100 gal (oz)	Spray applications[1]	Foliage disease rating[2]	
			Spring 1971 before spraying	Fall 1971 after spraying
Du-ter 47.5 WP	[3]0	0	[4]2.9	3.0
	12	1	3.0	2.7
	12	2	2.9	2.1
Bordeaux 8-8-100	0	0	3.0	2.8
	([5])	1	3.0	1.9
	([5])	2	2.9	2.1
Fundilan 75 WP	0	0	3.0	3.0
	96	1	2.9	1.0
	96	2	2.9	0.8
Ziram 76 WP	0	0	3.0	3.0
	96	1	2.8	2.7
	96	2	3.0	3.0

[1]The 1 spray was applied on June 23, 1971, the 2 sprays were applied on June 23 and August 10, 1971.

[2]Each rating is based on the average disease score on 30 trees.

[3]Unsprayed.

[4]Damage from brown spot was rated on a visual scale of 0 to 3. Trees rated 0 or 1 would be classified as merchantable Christmas trees.

[5]Bordeaux mixture was 8 lb copper sulfate and 8 lb lime/100 gal water.

results showed Bravo to be superior to Bordeaux mixture (table 8) but neither treatment was completely satisfactory. There was evidence that the trees in the center of the sprayed areas did not receive adequate coverage. There were 33 rows of trees between road systems, and this is considered to be too great a distance for complete foliage coverage.

The plantation near Poy Sippi was sprayed on June 15, 1972. Three treatments were tested: (1) Bravo W75 at 96 oz/100 gal water (plot size 2.25 acres); (2) Bravo W75 at 48 oz/100 gal water (plot size 2.25 acres); and (3) unsprayed area (2.35 acres). The road system was approximately every 20 rows. On October 11, 1972, a random sample of 100 to 200 trees from each treatment was rated

Table 8.--*Brown spot pilot fungicide test using air-blast mist blower, Black River Falls, Wis., sprayed on June 14, 1972*

Fungicide formulation	Rate/ 100 gal	Sample size	Spray applications	Foliage disease rating[1] fall 1972
	Ounces	*Number*	*Number*	
Bordeaux 8-8-100	([2])	100	1	2.0
Bravo 75 WP	96	100	1	1.7
No spray	--	100	0	2.5

[1]Damage from brown spot was rated on a visual scale of 0 to 3. Trees rated 0 or 1 would be classified as merchantable Christmas trees.

[2]Bordeaux mixture was 8 lb copper sulfate and 8 lb lime/100 gal water.

for brown spot symptoms. At Poy Sippi Bravo gave excellent control (table 9). The better control at Poy Sippi as compared to the Black River Falls plots can be attributed to more uniform fungicide coverage of the foliage. The plantation access roads at Poy Sippi were closer together and the mist blower was more powerful than the equipment used at Black River Falls.

Fungicide Control Summary

Based on 3 yrs of fungicide trials, we conclude that all of the fungicides tested will give adequate control in light to moderately infected plantations if applied when the newly emerging needles are approximately half their total length. In heavily infected plantations where the inoculum potential is high, a second spray may be needed 3 to 4 weeks later. In these heavily infected plantations only the more effective fungicides will give adequate control. In order of effectiveness, these are: Fundilan, Bravo, and Bordeaux mixture. At present, Fundilan is not available in the United States and is not registered for use on the brown spot disease. It therefore cannot be recommended at this time. Bravo and Bordeaux mixture are registered for brown spot needle disease control and, when used at the proper time with good foliage coverage, will give excellent control of the brown spot disease.

Table 9.--*Brown spot pilot fungicide test using air-blast mist blower, Poy Sippi, Wis., June 15, 1972*

Fungicide formulation	Rate/ 100 gal	Sample size	Spray applications	Foliage disease rating[1] fall 1972
	Ounces	*Number*	*Number*	
Bravo 75 WP	96	200	1	0.4
Bravo 75 WP	48	200	1	0.7
No spray	--	100	0	2.4

[1]Damage from brown spot was rated on a visual scale of 0 to 3. Trees rated 0 or 1 would be classified as merchantable Christmas trees.

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THIS IS ANOTHER OF OUR "NEW LOOK" RESEARCH PAPERS, designed (hopefully) to serve the special needs of each of our two major clients: the practitioner and the scientist.

Realizing that the needs and interests of our two major "clients"--the scientists and the practitioner--are different, we have been concerned whether our publications have been in a form and style equally useful to both. So we have decided to try a new format for some of our Research Papers, one that might serve this dual purpose better. You are about to sample the first fruit of this effort.

The Paper is divided into two separate parts: Application and Documentation. The Application section is specifically intended for the man on the ground or in the mill who has a particular job to do or problem to solve. This section describes briefly the situation and the problem, and then goes immediately to the solution, emphasizing the how-to-do-it aspect. It is a complete story in itself; the busy manager need read no further.

The Documentation section describes the details of the research process. It is for the reader interested in laboratory and field procedures, tabulations, statistical analysis, and philosophical discussion. This section, too, is self-contained.

Our purpose is to separate the practical aspects of our research results from the strictly academic ones yet still make both available to all readers. If the practitioner wants to find out how we arrived at our recommendations, the details are in the Documentation section for him to examine. If the scientist has a practical bent, he can turn to the Application section and see the results in action.

It is for you to decide whether we have created a well-matched team or a two-headed monster. *We would like to have your opinion.*